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Overview of Dryland Agriculture Research and Achievements in Kandi Region of Punjab

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Brief history of the Centre

Indian Council of Agricultural Research (ICAR), New Delhi sponsored an All India Coordinated Research Project for Dryland Agriculture in September 1970 located at Hoshiarpur under the control of Department of Soils, Punjab Agricultural University, Ludhiana with different operational stations from time to time. Presently, it is located at Ballowal Saunkhri, earlier in district Hoshiarpur and since 1990 in district Shahid Bhagat Singh Nagar. Before the establishment of Zonal Research Station at Ballowal Saunkhri in 1982, the project was operated in villages of district Hoshiarpur but subsequently it was shifted to Ballowal Saunkhri. The ORP centre was established in 1976.

Agro-climatic zone characteristics

AICRPDA centre Ballowal Saunkhri is located in the agro-climatic Zone-l in the North-Eastern part of the Punjab (agro-ecological sub-region 9.1) in the form of 10 to 20 km wide strip covering an area of approx. 3.929 lakh hectares which comprises approximately 7.8% of total geographical area of the State. This zone is located between 30°44′ and 32°32′ N latitude and 75°52′ and 76°43′ E longitude at an elevation of 300-500 m above mean sea level. The region stretches from Dhar Kalan block of Pathankot district to Dera Bassi block of SAS Nagar. The climate of the zone is semi-arid to sub-humid. The average annual rainfall is 1051 mm. The normal onset of monsoon is during first week of July and the normal withdrawal of monsoon is during fourth week of September. The maximum and minimum temperature during *kharif* season ranged from 31.9 °C to 40.8 °C and 21.4 °C to 26.2 °C, whereas during *rabi* season it varied from 16 °C to 38.9 °C and 2.3 °C to 20.4 °C, respectively.

Mean seasonal and annual rainfall and rainy days at AICRPDA centre, Ballowal Saunkhri

Season	Normal rainfall (mm)	Normal rainy days (No.)
Monsoon season (June - September)	840.7	38
Pre-monsoon (March - May)	86.6	8
Post-monsoon (October - December)	57.7	3
Winter seasons (January - February)	80.0	6
Annual	1064.7	5

Major soil types

The major soil types in the zone are loamy sand to sandy loam.

Major rainfed crops

The major rainfed crops cultivated in the zone during *kharif* are maize, blackgram, fodder bajra, sesame and greengram and during *rabi* are wheat, raya, taramira, gobhi sarson, toria, lentil and chickpea. Besides, field crops, vegetables crops such as ashgourd, cucumber and pumpkin during *kharif* and vegetable pea during *rabi* are also cultivated.

Socio economic characteristics

People of the area are generally poor, illiterate and tradition bound. They are not conversant with the improved technologies. The land holdings are small, fragmented and are generally degraded and poor in productivity. Majority of the farmers in this region are having holding of less than 2 ha which exist in small fragmented pieces. The farmers' capacity to invest is very limited. The farmers generally do not use inputs needed for high production, *viz.,* fertilizer, insecticides, pesticides and weedicides and improved seeds because of (i) uncertainty about the returns due to crop failure (erratic rainfall), (ii) poor economic condition and (iii) lack of awareness about improved technology (extension gaps). In the *Kandi* area, almost equal numbers to land holders are landless people who work as daily paid labourers. Farming as profession even with land holders is a subsidiary occupation, about 40% of them work at their farms and others go to cities for earning their livelihood.

Dryland agriculture problems

Soil and land management

- The land in the area is undulating
- Gullies and rills are commonly found in the area
- The organic carbon (<0.40%) is low and hence soils are highly dispersible and erodible
- A major portion (30-40%) of rain goes as runoff resulting in water erosion
- Poor inherent fertility of the soils along with inadequate supply of nutrients

Cropping systems

- Low and unstable crop yields
- Poor mechanization of farming

- Insect-pest problems

Socio-economic status

- Lack of adequate infrastructure
- Poor dairy animal breeds and nutritional status
- Small and fragmented land holdings
- Wild life damage

Significant achievements

Field experiments under rainfed conditions as per mandates of AICRPDA were conducted at Regional Research Station (P.A.U.), Ballowal Saunkhri to study the effect of low till farming strategies and crop residue management on resource conservation and improvement of soil quality, improvement of crop productivity by integrated nutrient management practices, application of locally available mulch material, thiourea application, seed priming, intercropping, evaluation of improved varieties under rainfed conditions, phosphorus and sulphur management with seed inoculation in chickpea, rain water management, integrated farming systems, precision levelling and contingency crop planning for seasonal drought conditions under rainfed conditions.

Rainwater management

***In-situ* moisture conservation**

- Levelling of individual fields with minimum cut and fill with prefabricated outlets for drop of <50 cm, brick masonary structure for large drop, terracing, along with grassed waterways resulted in low runoff, soil loss and higher crop yields.
- Ploughing of fields about a month before onset of monsoon results in more infiltrating water, low run off and soil loss. The effect was more pronounced in case of early withdrawn of monsoon.
- Post-sowing tillage operation during *kharif* either as hoeing or inter-culturing (holding) increased water intake, controlled weeds and act as soil mulch reducing evaporation losses thereby enhancing maize yield.
- Repeated shallow tillage followed by planking immediately after harvesting of *kharif* crops helps in conserving moisture for the sowing of next *rabi* crop. Preferably the field is ploughed in evening and planked next morning to conserve dew drops fallen at night.
- Locally available shrubs like basooti (*Adhatoda vasica*), nara (*Arundodonax spp*) and Kanna (*Saccharum munja*) @ 4 t/ha applied in standing maize during last week of August resulted in higher soil moisture and higher wheat yields particularly in low rainfall years. Mulching also improved yield of rainfed sugarcane crop.
- *In-situ* raised mulch by growing green manure crops of sunhemp or cowpea in between the furrow of maize, which was cut at age of one month and spread in between the maize rows, resulted in significant increase in maize and wheat yields.
- Cultivation across the slope reduces velocity of runoff water resulting in lower soil loss and higher soil moisture content.
- Suitable grasses and bushes raised on field boundaries across the slope are the alternatives to bunding on arable lands resulting in increased soil profile storage and reduce soil erosion. In addition, napier bajra hybrid *(Pennisetum purpureum X typhoides*) gave higher biomass during initial years and Kanna (*Sachharum munja*) gave higher mass in subsequent years.
- V-ditch and crescent bund methods of planting for horticultural and forestry plants on slopy lands harvest higher *in-situ* moisture. Success rate of plantation was higher by planting trees in V-ditches in clayey soils on upper side of ditch, whereas in soils with good infiltration rate, plants should be placed in ditch.
- In maize-wheat cropping system flat laser levelling of field helped in conserving 32.7% more moisture along with reduced runoff and soil loss and resulted in 15.5% higher grain yield of maize over conventional levelling. It also resulted in highest BC ratio (2.17) and WUE (7.40 kg/ha/ mm^{-1}).
- In maize, in situ moisture conservation practices like ridge planting, conservation furrows and bed planting resulted in significant increase in the yield of maize over flat sowing with a respective increase of 17.4, 15.1 and 10.3 per cent. The yield of succeeding rainfed wheat in ridge sowing and conservation furrow plots of maize increased by 20.3 and 15.7 per cent respectively over flat sowing.

***Ex-situ* moisture conservation**

- In Kandi region it is estimated that 25 to 45% of the monsoon rain is lost as runoff. The runoff water can be harvested in excavated or impounded type reservoirs and can be used for irrigation and other purposes. To reduce seepage losses, 800 gauge (200µ) polythene sheet covered under 20 cm layer of soil was quite effective for lining tank bottoms, whereas brick and cement lining (7.5 cm thick) was effective for lining the sides of tank.
- Perennial flow on base flow from the drainage line was harvested at Hoshiarpur district of Punjab for the first time with technical support of AICRPDA, Ballowal Saunkhri. The model was replicated with the help of World Bank at many locations in *Kandi* region.

- A farm pond was developed at AICRPDA centre Ballowal Saunkhri in 2015 to harvest the rain water from the catchment area of about 1.8 ha. The farm pond is trapezoidal in cross section having the storage capacity of 696 m^3 water. The lining of farm pond has been done by cement and soil (1:8 ratio) mixture and gravel in 1×1 compartment. The harvested rainwater is lifted using 1 HP solar powered pump. Supplemental irrigation through micro-irrigation system in maize and okra resulted in 36.8% and 28.0% higher yield over rainfed maize and okra, respectively. In *rabi* season harvested water in farm pond applied judiciously as supplemental irrigation in wheat at CRI stage gave 41.7% higher yield over rainfed wheat.
- Use harvested water for pre-sowing irrigation in case of deficit seed zone moisture for *rabi* crops. If seed zone moisture at sowing is sufficient, one supplemental irrigation to wheat at crown-root initiation is best. The irrigation to wheat at large areas was found beneficial over two irrigations on smaller area. If there is dry spell during tasseling and pollination phase of maize crop, use harvested water as life-saving irrigation.
- Application of one supplemental irrigation to maize & okra during dry spell, at CRI stage to wheat and as pre-sowing irrigation to pea gave 50, 51, 93 and 100% respectively, higher yield over rainfed conditions.

Cropping systems

Crops and cropping system available for the region: Maize was found to be most suitable and assured crop during *kharif* season. In case of sandy soils with low moisture holding capacity pearl millet for fodder purpose performed better than maize. Performance of *rabi* crops was better after summer fallow than after maize. The combined yield of two crops per year was always considerably higher than that of a single *rabi* crop. Maize-wheat sequence was best in years of favourable rainfall whereas maize-wheat+gram sequence performed better in low rainfall years. Sunflower and safflower can be cultivated successfully under rainfed conditions.

Green manuring and use of leguminous crops: The yield of *rabi* crops was better after green manuring rather than after maize crop or after summer fallow. Growing of short duration legume crop of moong gave an additional yield of 3 to 4 q/ha and proved even better than green manuring. Green manuring with 40 days old sunhemp crop was better than that of 30, 50 or 60 days old crop in terms of wheat yield.

Inter-cropping

- Sowing of 2-4 rows of pearl millet around maize fields saved maize crops from animal and human damage, worked as wind break and provided fodder for livestock.
- Wheat + raya in rows (One row of raya after every 12 rows of wheat) proved more remunerative compared to wheat alone.
- Intercropping of greengram/blackgram between two rows of maize spaced 50 cm gave higher maize equivalent yield as compared to sole maize.
- Intercropping of green gram in paired row of maize (30/60 cm) resulted in highest maize equivalent yield followed by blackgram.
- Raya intercropping in wheat and gram at 3.0 m apart in north-south direction and in lentil at 2.0 m apart provided additional income and covered the risk of crop failure under rainfed conditions.

Strip-intercropping

- Cultivation of maize and cowpea on 1% slope gave significantly higher yield (3331 kg/ha), net returns (Rs.23202 /ha), BC (1.75) and WUE (6.22 kg/ha/mm) than 2% and 3% slope. A strip intercropping system with maize strip width of 4.8 m and cowpea strip width of 1.2 m (4.8:1.2) gave significantly higher maize equivalent yield (MEY) (3862 kg/ ha) over maize: cowpea strip width of 3 m: 3 m, 1.2 m: 4.8 m and sole cowpea with a respective increase of 8.9, 17.8 and 32.8 per cent with highest LER (1.22), net returns (Rs.28428/ ha) and WUE (7.18 kg/ha/mm^{-1}).
- Strip-intercropping of maize in 6 m and blackgram in 2.4 m wide strips gave 9.3% higher yield over sole blackgram and 10.9% over sole maize.

Double cropping

- Soils of high and medium water holding capacity were suitable for maize- wheat system.
- If sufficient moisture is available after *kharif* crop, raya in *rabi* is most profitable.
- On sandy soils with low water holding capacity, summer fallow was better than double cropping.
- Total productivity of cropping sequence was higher in blackgram-raya, maize-raya and maize-chickpea sequence or compared to traditional maize-wheat sequence. Thus, cultivation of raya and chickpea was found to be more profitable when grown after blackgram maize crops respectively.

Triple cropping systems

- Maize-toria-late sown wheat cropping system resulted in maize equivalent yield of 10616 kg/ha which was 18.3 higher than maize-wheat cropping system.

RTCPs identified for early/midseason/terminal droughts

Based on the experiments conducted at the station and on the farm the following real time contingency measures have given

promising results in alleviating moisture stress in maize and blackgram crop during dry spells and low moisture conditions.

Real time contingency measures for early season drought

- Hoeing with wheel hand hoe to control weeds and create soil mulch to reduce transpiration and evaporation losses
- Maintain optimum plant population by removing closely spaced plants
- Use harvested rainwater for life saving irrigation, if available
- Apply foliar spray of 1% KNO_3 or 19:19:19 @ 0.5% + $ZnSO_4$ @ 1% or Urea 2% or Zinc sulphate @ 1%
- In case of crop failure grow alternate crops like sesame and blackgram up to mid-July; greengram in second fortnight of July and fodder pearl millet in early August.
- Avoid top dressing of nitrogen until moisture conditions are favourable
- If crop fails due to the prolonged dry spell, then fodder bajra may be sown in the month of August.

Real time contingency measures for mid-season drought

- Apply life-saving irrigation, if available
- Remove up to 20% less vigorous plants and use them as fodder
- Remove weeds to avoid competition for water.
- Apply locally available vegetative mulch material in between crop rows
- Apply foliar spray of 1% KNO_3 or 19:19:19 @ 0.5% + $ZnSO_4$ @ 1% or Urea 2% or Zinc sulphate @ 1%
- Every third row in case of maize/pearl millet can be thinned out and used as fodder (1/3rd population)
- If grain is set in maize, the tassels can be cut down to reduce transpiration
- Greengram and blackgram can be incorporated as green manure and conserve moisture for *rabi* crops

Real time contingency measures for terminal drought:

- Remove cob-less plants and use as fodder
- If crop is at milking stage, harvest and sell the green cobs in market.
- At dough stage, harvest the crop and do vertical staking of the crop.
- Apply life-saving irrigation, if available.
- Apply foliar spray of 1% KNO_3 or 19:19:19 @ 0.5% + $ZnSO_4$ @ 1% or Urea 2% or Zinc sulphate @1%
- If field is vacated due to early maturity of crop, then cultivate the field to conserve moisture for *rabi* crops.
- Harvest maize crop at physiological maturity in order to conserve soil moisture by immediately ploughing and planking the field.
- With sufficient soil moisture, toria or vegetable pea can be sown in mid-September as sole crop or toria+ gobhi sarson can be sown as intercrop (1:1).
- Late sown wheat varieties (PBW 752 and PBW 771) can be sown in December or very late sown wheat variety (PBW 757) may be sown in January after the harvest of toria and pea.

Real time contingency measures for delayed onset of monsoon

- If monsoon onset is delayed by 15 days sow alternate crops like greengram, blackgram and sesame.
- If monsoon onset is delayed by 30 days sow greengram for grains or pearl millet for fodder.

Real time contingency measures for *rabi* cropping

Scenario I: Low soil moisture at sowing

- Placing the seed in the moist soil zone ensures uniform germination of the crop.
- Sowing of wheat at wider row spacing of 30 cm is better than 22-25 cm.
- Chickpea, linseed and rapeseed and mustard perform better than wheat in low soil moisture.
- Sowing of chickpea after seed priming in molybdenum solution (1 g molybdenum per 2 litres of water) ensures better germination and higher yield of the crop.
- Sowing of wheat crop after soaking seed in thiourea solution (1 g thiourea per litre of water) results in uniform germination and higher yield.
- Late sown varieties of wheat like (PBW 752 and PBW 771) can be sown in December or very late sown wheat variety (PBW 757) may be sown in January after the receipt of winter rains.

Scenario II: Failure of winter rains

- Apply supplemental irrigation from the harvested rain water to save the crop.
- Application of foliar spray of thiourea solution (1g thiourea per litre of water) to wheat at maximum tillering and booting stage increases grain yield.

Nutrient management

Nutrient management in *kharif* crops

Maize:

- In Sandy loam soils having medium water storage, 80 kg N/ha is optimum whereas for loamy sand soils with low water storage 40 kg N/ha is optimum.

- The response to applied P was observed only for soils testing low in available P and that too only up to 20 kg P_2O_5/ha .
- All source of N in two splits i.e. ½ at sowing and ½ at knee high stage proved slightly better than full N at sowing. Foliar application of N was not beneficial.
- Application of 10 t/ha FYM increased maize yield by about 3 q/ha but the effect was observed in low N application only.
- Application of crop residues reduced maize yield by 50% as compared to control. During initial two years, application of wider C:N ratio plant residues alone (maize stover and wheat straw) showed depressing effect but during 3rd year onwards the response was encouraging.
- Equal yields were obtained with 100% inorganic N and 50% organic + 50% inorganic N.
- Application of 40 kg K_2O/ha resulted in 18.6 and 10.7% higher grain yield of maize over control and 20 kg K_2O/ha, respectively. Magnesium sulphate application @ 45 kg/ha improved yield of maize.

Fodder crops:

- Bajra and fodder sorghum responded to N up to 50 kg/ha.
- Napier bajra hybrid responded up to 50 kg/ha applied after each cutting.

Nutrient management in *rabi* crops

Wheat:

- Early tall wheat varieties line C-306 responded up to 30 kg N/ha only in loamy sand soils.
- High yielding late varieties responded up to 80 kg N/ha in medium storage soils and up to 120 kg N/ha in soils of high moisture storage.
- Different sources of N like urea, calcium ammonium nitrate and ammonium chloride were equally effective however ammonioum chloride was slightly inferior in performance.
- Application of half of recommended N as basal and remaining half with winter rains proved economical.
- Early tall wheat varieties were not responding to P application but late dwarf varieties responded up to 20 and 40 kg P_2O_5 in loamy sand and sandy loam soils respectively.

Chickpea:

- Response of gram to P application on soils with 16 kg available P_2O_5/ha or less, was up to 20 kg P_2O_5/ha.
- In Wheat + gram mixture, response to N was observed up to 60 kg N/ha in clay loam and sandy loam soils, whereas it was up to 20 kg N/ha in loamy sand soils.
- Seed priming of gram with molybdenum increased seed yield up to 0.5 g/litre of water compared to control.
- Application of P+S to rainfed gram gives highest seed yield.
- Seed inoculation with *Rhizobium* gave better yield and economic returns than control.

Lentil:

- Seed inoculation with *Rhizobium* culture and fertilizer application of N @12.5 kg and P_2O_5 @ 20 kg/ha gave higher crop yields.
- Green manuring with green gram along with recommended fertilizers gave highest yield.

Oilseeds:

- Application of 50 kg N/ha to sole toria , 75 kg N/ha to sole gobhi sarson is optimum.
- For toria-gobhi sarson intercropping system, application of 30 kg N/ha to toria and 50 kg N/ha to gobhi sarson is better.

Maize-wheat cropping system:

- In maize-wheat cropping system application of FYM @10 t/ha benefitted both maize and wheat crop in normal rainfall years.
- In maize-wheat sequence when FYM is applied to maize, a saving of 50% N can be made in case of the succeeding wheat crop.
- Wheat crop responded up to 20 kg P_2O_5/ha but there was no residual effect of P applied to maize on wheat. Long term application of P to wheat showed its residual effect on maize crop.

Tillage and nutrient management

In maize-wheat rotation, 50% conventional tillage + interculture + chemical weed control was at par with conventional tillage+interculture, thus saving two tillage operations. Among N sources, application of 100% N through urea gave best results.

Permanent manurial trial

In maize-wheat cropping system, application of 100% recommended NPK + FYM @ 10 t/ha gave highest yield of maize and wheat which was significantly higher over all other treatments.

Crop improvement/evaluation of drought tolerant varieties

- Maize: Local varieties sown earlier were maturing earlier that resulting in more residual soil moisture and better *rabi* crop yields but these were replaced with composites and hybrids because of their low yield potential. Prominent composite varieties were Megha and Kesari whereas prominent recommended hybrids were Prakash, JH-3459 and PMH-2. Newly developed composites are JC12 & JC4.
- Bajra: HB-1 was best variety in seventies, followed by PHB47, PCB8 and PHB10, PCB15 and PCB138 in eighties and nineties. In the beginning of twenty first century PCB164 and PHB 2168 were recommended for grain purpose and FBC16 and PHBF-1(hybrid) for fodder purpose.

- Sesamum: Earlier sesamum IVI 24 was best but later on, TC289, RT346, Punjab Til No. 1 and Punjab Til No.2 were recommended.
- Blackgram mash: Mash 1-1 in seventies, Mash 48, then Mash 338 and Mash 114 were recommended. KUG 882 is recently recommended for the farmers of the domain area.
- Greengram moong: ML 131 and ML 267, ML613, were earlier varieties which were replaced by ML818, ML 2056, ML 1808 and PAU911 under rainfed conditions.
- Wheat: In late seventies under low rainfall conditions tall variety C306 was best but in normal rainfall years dwarf varieties WL 357, WL 410 and PBW 2265 were better. Later on PBW 175, PBW 299, PBW 644 and PBW 660 were recommended for cultivation. Late sown wheat varieties PBW 752, PBW 757 & PBW 771 are found promising for late sowing in December after receipt of rains.
- Barley: In recent years PL426, PL56 and PL419 were found better than local varieties.
- Gram: Till early eighties C235 was best variety. Later on PBG-1, PBG-5 and PBG-7 were recommended.
- Lentil: Earlier L 9-12 was best but later on LL699 and LL931 were recommended.
- Raya: Earlier RL18 and T59 were significant but later on PBR91, PBR97 and RLM619 were tested and released.
- Taramira: TMLC-2 variety of taramira was recommended.
- Linseed: LC54 variety of linseed performed well in dry land conditions.

Crops for animal damage prone areas:

- Safflower strains ISF-1, SPP-A-129 and MKH-9 were better than local check Bhima. Because of thorns this crop is not damaged by wild animals.
- Sesamum during *kharif* season and taramira during *rabi* season are suitable alternate crops as they perform better than other crops in animal damage prone areas.

Energy management/ farm mechanization

In maize-wheat cropping system, conventional tillage (Disc harrow + cultivator + planking) resulted in 15.0 and 5.0% higher grain yield of maize and wheat over rotavator.

Alternate land use system

Agroforestry: Planting of Kikar (*Acacia nilotica*) and Safeda (*Eucalyptus spp*) in blocks at 3x5 m spacing performed best. Under these trees in *kharif* season fodder crops and in *rabi* season oilseed crops can be grown.

Agro-horticulture

- Amla, Galgal, Ber, Guava and Mango can be grown in rainfed kandi region. These trees can be planted at 7.5 x 7.5 m distance.
- Up to the age of 4 years of these trees, intercropping with leguminous crops can be done.
- Grasses could also be grown successfully as intercrops in these orchards.
- Fruit based agri-horticulture system like amla + blackgram, guava+blackgram during *kharif* and amla + taramira, guava + taramira, amla + lentil and guava + lentil during *rabi* were better than annual crops.

Technologies developed

Rainwater management

- Minor landshaping of slopy field for soil and water conservation
- Summer ploughing for enhancing rain water intake
- Haloding (Earthing-up) in maize with bullocks or tractor drawn ridger for *in-situ* moisture conservation
- Moisture conservation for *rabi* crops with post-harvest tillage
- Mulching with locally available shrubs for *in-situ* moisture conservation in maize-wheat cropping system
- *In-situ* raised mulch of leguminous crops in maize for *in-situ* moisture conservation in maize-wheat cropping system
- Vegetative mulching for establishing spring planted sugarcane on medium to heavy textured soils in beet region of *Kandi* area
- Sowing crops across the slope or along contour lines for soil and water conservation
- V-ditch and crescent bund methods for planting horticultural and forestry plants on sloppy land
- Rainwater harvesting in farm pond and its efficient utilization for life-saving irrigation during dry spell in maize
- Makowal type water harvesting structures to harvest water from hill seepage and base flow
- Establishment of vegetative barriers (Napier-Bajra hybrid) on field bunds for soil and water conservation under sloppy land conditions
- Higher wheat productivity in *Kandi* region through supplemental irrigation with harvested rainwater
- Ridge sowing of *kharif* maize for higher productivity of maize and succeeding wheat
- Conservation furrow planting method for higher productivity of rainfed maize-wheat cropping system

Crops and cropping systems

- Sowing of maize at wide row spacing to facilitate intercultural operations
- Sowing depth and spacing of rainfed wheat based on residual soil moisture at sowing

- Optimum sowing time of chickpea in *Kandi* region of Punjab
- Toria + gobhi sarson (1:1) intercropping system for better returns
- Maize-toria-late sown wheat contingency cropping system
- Maize and cowpea strip-intercropping on slopy lands for resource conservation and sustainable productivity
- Integrated weed management in blackgram and greengram

Inter-cropping systems

- Maize and cowpea strip-intercropping with maize strip 4.8m and cowpea strip width 1.2 m
- Maize and mash strip-intercropping with maize strip 6.0 m and mash strip width 2.4 m
- Wheat + Raya (6:1)
- Wheat + Chickpea (6:1)
- Toria + Gobhi sarson (1;1)

Double cropping systems

- Maize - Wheat
- Maize - raya
- Maize - taramira
- Maize - chickpea
- Ash gourd - taramira
- Ash gourd - wheat
- Maize-toria- late sown wheat

Nutrient management

Integrated nutrient management practices

Crops	INM Practice
Maize	100% NPK + FYM 10 t/ha or 50% N through FYM or compost + 50% through urea
Blackgram	Inoculate the seed with *Rhizobium* culture at the time of sowing and apply full dose of N and P_2O_5.
Greengram	Inoculate the seed with *Rhizobium* culture at the time of sowing and apply full dose of N and P_2O_5.
Sesame	20 t/ha FYM + 50 kg N/ha
Wheat	100% NPK + FYM 10 t/ha; or 50% N through FYM or compost + 50% N through urea and 100 % P_2O_5 & K_2O.
Chickpea	Inoculate the seed with *Mesorhizobium* (LGR-33) and *Rhizobacterium* (RB-1) biofertilizers
Lentil	Inoculate the seed with *Rhizobium* culture at the time of sowing and apply full dose of N and P_2O_5.
Maize	Application of C1 consortia biofertilizer (*Pseudomonas putida* P7 + *Bacillus subtilis* B30) and C2 consortia biofertilizer (*Pseudomonas putida* P45 + *Bacillus amyloliquefaciens* B17) in maize

Foliar nutrition

Crops	Foliar spray	Time of application
Maize	Potassium nitrate @1%	During dry spell at knee high stage or tasselling or grain filling stage
	19:19:19 @ 0.5% + $ZnSO_4$ @ 1%	During or after dry spell
	Urea @ 2%	After dry spell
	Zinc sulphate @1%	During or after dry spell
	Urea @ 3%	Spray at early stages to reduce the damage caused to root system by flooding
Wheat	Apply two sprays of potassium nitrate (13:0:45) @ 2% or apply two sprays of salicylic acid (dissolve 37.5 gram salicylic acid in 1125 ml of ethyl alcohol) by using 500 litres of water per hectare	At boot leaf and anthesis stages to mitigate the effect of high temperature at grain filling
Chickpea	Urea @ 2%	At 90 and 110 days of sowing

Energy management

- Reduced tillage for maize-wheat cropping system under rainfed conditions
- Tractor operated seed-cum-fertilizer drill for higher productivity of wheat in *Kandi* region of Punjab
- Laser levelling for resource conservation in sloppy fields
- Wheel hand hoe for efficient weeding for rainfed crops in *Kandi* region of Punjab

Alternate land use

- Sesame as an alternate crop during *kharif* season in wild/ stray cattle menace prone areas
- Sesame a profitable alternate crop under delayed monsoon in *Kandi* region
- Groundnut as an alternative crop to maize in lower *Kandi* region of Punjab
- Taramira crop for minimizing wild animal menace
- Ash gourd as an alternate crop during *kharif* season in wild/ straycattle menace prone areas
- Guava and aonla based agroforestry systems for sustainable land use

Agroforestry systems

a. Agri-hortisystem

- Guava + blackgram/greengram during *kharif* and lentil/ taramira during *rabi*

- Aonla + blackgram/greengram during *kharif* and lentil/ taramira during *rabi*
- Spacing: Guava - 6 m x 5 m; Aonla - 7.5 m x 7.5 m
- Intercropping with *kharif* crops can be done up to 4 years in guava and aonla to 4 years while *rabi* crops can be taken up for longer period.

b. Agi-horti-silvi-pasture system

- Guava + *Grewia optiva* (fodder tree) + *Setaria* grass + blackgram-wheat
- 67% area is under field crops (Blackgram-wheat system), 20% area is allocated for *Setaria* grass and 13% area for fruit and fodder tress.
- Guava + *Grewia optiva* are plantd at inter and intra row spacing of 6 m x 3 m. Two rows of *Setaria* grass are planted in the intra row spaces. During *kharif* season blackgram is sown as an intercrop in guava + *Grewia optiva* and during *rabi* wheat is sown as intercrop. Blackgram and wheat are sown at row to row spacing of 30 cm and 22.5 cm, respectively.

Contingency crop planning

For *kharif* planning

a. Suggested contingency crops/cropping systems and cultivars under delayed onset of monsoon

Delay by 2 weeks (3rd week of July)

- Blackgram (Mash 114, Mash 338); Greengram (ML 1808, ML 2056)

Delay by 4 weeks (2nd week of August)

- Greengram (ML 1808, ML 2056); Fodder pearl millet (FBC-16)

Delay by 6 weeks (4th week of August)

- Fodder pearl millet (FBC-16)

Delay by 8 weeks (2nd week of September)

- Keep the field fallow and conserve the moisture for succeeding *rabi* crops
- Toria + Gobhi Sarson intercropping (1:1)
- Sole crop of toria followed by late sown wheat in December

b. Crop, soil, water and nutrient management strategies during seasonal drought

Early season drought

- Hoeing with wheel hand hoe to control weeds and create soil mulch to reduce transpiration and evaporation losses
- Maintain optimum plant population by removing closely spaced plants
- Use harvested rainwater for life-saving irrigation, if available
- Apply foliar spray of 1% KNO3 or 19:19:19 @ 0.5% + $ZnSO_4$ @1% or Urea 2% or Zinc sulphate @ 1%
- In case of crop failure grow alternate crops like sesame and blackgram up to mid-July; greengram in second fortnight of July and fodder pearl millet in early August.
- Avoid top dressing of nitrogen until moisture conditions are favourable

Mid-season drought

- Apply life-saving irrigation, if available
- Remove up to 20% less vigorous plants and use them as fodder
- Remove weeds to avoid competition for water.
- Apply locally available vegetative mulch material in between crop rows
- Apply foliar spray of 1% KNO_3 or 19:19:19 @ 0.5% + $ZnSO_4$ @ 1% or urea 2% or $ZnSO_4$ @ 1%
- Every third row in case of maize/pearl millet can be thinned out and used as fodder (1/3rd population)
- If grain is set in maize, the tassels can be cut down to reduce transpiration
- Greengram and blackgram can be incorporated as green manure and conserve moisture for *rabi* crops

Terminal drought

- Remove cob-less plants and use as fodder
- If crop is at milking stage, harvest and sell the green cobs in market.
- At dough stage, harvest the crop and do vertical staking of the crop.
- Apply life-saving irrigation, if available.
- Apply foliar spray of 1% KNO_3 or 19:19:19 @ 0.5% + $ZnSO_4$ @ 1% or urea 2% or $ZnSO_4$ @ 1%
- If field is vacated due to early maturity of crop, then cultivate the field to conserve moisture for *rabi* crops.
- Harvest maize crop at physiological maturity in order to conserve soil moisture by immediately ploughing and planking the field.
- With sufficient soil moisture, toria or vegetable pea can be sown in mid-September as sole crop or toria+ gobhi sarson can be sown as intercrop (1:1)
- Late sown wheat varieties (PBW 752 and PBW 771) can be sown in December or very late sown wheat variety (PBW 757) after the harvest of toria and pea

For *rabi* planning

a. **Suggested crops and varieties for delayed season**

Sometimes due to the early withdrawal of monsoon soil moisture is not adequate for sowing, under such conditions wheat can be

sown after the receipt of winter rains in December. Under this situation, recommended wheat varieties are PBW 752 and PBW 658 can be sown.

Technologies upscaled in convergence with various programmes

The following technologies were upscaled in convergence with various national, state and district programmes:

- Summer ploughing for enhancing rain water intake
- Mulching with locally available shrubs for *in-situ* moisture conservation in maize-wheat cropping system
- Vegetative mulching for establishing spring planted sugarcane on medium to heavy textured soils in beet region of *Kandi* area
- Rainwater harvesting in farm pond and its efficient utilization for life-saving irrigation during dry spell in maize
- Makowal type water harvesting structures to harvest water from hill seepage and base flow
- Establishment of vegetative barriers (Napier-Bajra hybrid) on field bunds for soil and water conservation under sloppy land conditions
- Higher wheat productivity in *Kandi* region through supplemental irrigation with harvested rainwater
- Ridge sowing of *kharif* maize for higher productivity of maize and succeeding wheat
- Conservation furrow planting method for higher productivity of rainfed maize-wheat cropping system
- PBW 660: Improved wheat variety for cultivation under rainfed conditions
- Improved variety of Pearl millet (Fodder)
- Sowing of maize at wide row spacing to facilitate intercultural operations
- JC-12: A new composite maize variety for cultivation under rainfed conditions
- Potassium and magnesium application in rainfed maize to enhance drought tolerance and increase productivity
- Foliar spray of potassium nitrate for mitigating dry spells in rainfed maize
- Tractor operated seed-cum-fertilizer drill for higher productivity of wheat
- Sesame a profitable alternate crop under delayed monsoon
- Ashgourd as an alternate crop during *kharif* season in wild/ straycattle menace prone areas

Impact of technologies

The impact of various dryland technologies developed at the AICRPDA centre, Ballowal Saunkhri is given as under:

- Landshaping was done by most of the farmers in Hoshiarpur, SBS Nagar, Pathankot and Roopnagar districts of *Kand*i region. This technology has already been adopted by the majority of the farmers' in the domain area.
- Summer ploughing is adopted by 45 per cent of farmers in domain of the AICRPDA centre, Ballowal Saunkhri. Further extension efforts by line departments and government schemes can spread this technology on a larger scale in farmers' fields.
- The hoeing and holding technique were used in most of the area under maize cultivation in *Kandi* region and presently covers over 60% area in the domain districts. Extension efforts through demonstrations and other government schemes can push this technology in farmers' fields along with assistance from the KVKs in the domain of AICRPDA centre.
- The technique of moisture conservation by ploughing and planking is practiced by 60 per cent farmers in domain districts of AICRPDA centre in *Kandi* region. Extension efforts through demonstrations and other government schemes can push this technology in farmers' fields along with assistance from the KVKs in the domain of the AICRPDA centre.
- The technique of moisture conservation by locally available vegetative mulch is adopted on a limited scale by the farmers as it requires considerable human labour for collection and spreading and there is also difficulty in spreading the material in standing crop. Extension efforts through demonstrations and other government schemes can push this technology in farmers' fields along with assistance from the KVKs in the domain of the AICRPDA centre.
- The technique of moisture conservation by *in-situ* raised mulch is adopted on a limited scale by the farmers. Extension efforts through demonstrations and other government schemes can push this technology in farmers' fields along with assistance from the KVKs in the domain of the AICRPDA centre.
- The area under sugarcane is increasing in *Kandi* region. Presently it is cultivated in *'beet'* area of Hoshiarpur districts. Extension efforts through demonstrations and other government schemes can push this technology in farmers' fields along with assistance from the KVKs in the domain of the AICRPDA centre.
- Sowing across the slope has shown a marked increase in the yield of crops as compared with the sowing along the slope method. So, most of the farmers cultivating maize, wheat and other crops on undulating fields sow their crops across the slope. Further upscaling can be done through extension efforts by line departments and KVKs.

- The technology of V-ditch method of planting for horticultural and forestry plants on sloppy land can be upscaled through demonstrations by line departments and KVKs situated in the domain of the AICRPDA centre.
- The technology of constructing water harvesting pond is new to the farmers and only few such water harvesting structures are available with the individual farmer. However, community water harvesting ponds on village panchayat land are available in the *Kandi* region. Large-scale adoption can be achieved with the government support by giving subsidy on solar pump and construction cost.
- After introduction of Makowal type water harvesting system there was 14.4%, 5.9% and 3.8% improvement due to crops, dairy farming and agroforestry, respectively. After its success in village Makowal, this water harvesting structures were replicated in about 110 other places in the *Kandi* region.
- Farmers in the domain area are adopting this technology as it controls soil erosion and conserves soil moisture for the succeeding *rabi* crops. Extension efforts through exposure visits to the farmer fields adopting this technology by state agriculture department and KVKs will further increase the adoption of vegetative barrier on field bunds.
- The adoption of this technology will increase the wheat yield in rainfed areas and reduce the risk of crop failure under adverse weather conditions. The technology is widely accepted by the farmers and can be further upscaled through trainings/demonstrations by line departments and KVKs.
- One row of maize is sown on the side of the ridge 6-7 cm above the base at 60 cm x 20 cm. Sowing on ridges helps to avoid the adverse effect of excess rainfall, particularly at seedling emergence during *kharif* season. The furrows act both as drainage channels during high rainfall events and as moisture conservation furrows when rainfall is low. The moisture stored in the soil profile is utilized by existing and succeeding crops during moisture deficit conditions.
- Ridge sowing of maize is a useful climate resilient technology under rainfed conditions as furrows act both as drainage channels during high rainfall events and as moisture conservation furrows when rainfall is low. It gives higher yield of maize and wheat crop than flat sowing. The extension efforts through FLDs through different State Agriculture Department schemes as well as KVKs can promote this technology to benefit the farming community.
- Conservation furrow method of planting maize is a climate resilient technology as furrows act both as drainage channels during high rainfall events and as moisture conservation furrows when rainfall is low. It gives higher yield of maize and wheat crop than flat sowing. The extension efforts through FLDs through different State Agriculture Department schemes as well as KVKs can promote the strip cropping to benefit the farming community.
- The farmers appreciated the advantages of sowing maize at wider row spacing (45 and 60 cm) as compared to existing practice (30 cm), though there was no increase in maize yield due to wider row spacing. The farmers however adopted this practice due to the ease of intercultural operations and less requirement of labour. The row spacing of 60 cm is relevant in the present time. So, it needs to be expanded in the domain districts with the support of line departments and KVKs in the domain of the AICRPDA centre.
- The area under PBW 660 is increasing in *Kandi* region and presently this variety cover about 30 % of the total area under rainfed wheat in Shahid Bhagat Singh Nagar, Roopnagar and Hoshiarpur districts. Further extension efforts through FLDs, NFSM, ATMA, RKVY and other government schemes can popularize this variety among farmers.
- The area under FBC 16 is increasing in *Kandi* area and presently covers about 20% of the total area under pearl millet (fodder) in Shahid Bhagat Singh Nagar and Hoshiarpur districts. Further extension efforts through FLDs, NFSM and other government schemes can popularise this variety among farming community.
- Late sown wheat varieties have increased the cropping intensity in the rainfed areas as they can be sown after the harvest of toria and vegetable pea. Further extension efforts through FLDs, NFSM, ATMA, RKVY and other government schemes can popularize this variety among farmers.
- Potassium and magnesium application in rainfed maize is demonstrated in NICRA villages which resulted in higher yield than farmer practice. It needs to be demonstrated and up scaled further with the support of line departments and KVKs.
- The technology of potassium nitrate spray during dry spells application to maize is a promising technology but is adopted on a limited scale by the farmers of the domain area. It needs to be demonstrated on a large scale through demonstrations by line departments and KVKs to make it acceptable among the farmers.
- About 50 per cent farmers in adopted village of SBS Nagar and Hoshiarpur districts currently use this seed cum fertilizer drill. Large scale adoption can be achieved by more demonstrations by KVKs and line departments.
- Laser land levelling not only conserves moisture in rainfed conditions but also improve the efficiency of other agricultural inputs. This also results in uniform maturity of

the crop, better quality and higher yield. Keeping in view the benefits of laser land levelling technology farmers of the *Kandi* region have readily adopted this technology and it needs to be further promoted in a big way through Govt. and Non-Govt. organizations.

- The area under sesame is less than 1% in the domain region but farmers are now shifting from maize to sesame cultivation in the domain area due to lower cost of cultivation and higher returns besides less damage by wild/stray cattle.
- Ash gourd has become the main cash crop for *kharif* season in the *Beet* area. Farmers are getting very good price in the market which has increased the economic status of the farmers. Further upscaling can be done through extension efforts by line departments, KVKs, besides taking up seed production. This would reduce the menace of the wild animals in the region to a great extent.

Way forward

AICRPDA centre, Ballowal Saunkhri has been working since 1970. During this period there has been tremendous progress in all fields of agriculture. The farmers of the region have been benefitted from the technologies developed by the centre. The research outcomes have been transferred to the farmers of the region which resulted in improvement in rural livelihood in the region. However, during the last 5-7 years, the agriculture in the region has become vulnerable to the factors like climate change, increased damage of crops by wild animals, etc. The centre has given recommendations to the farmers based on the research carried out at the centre on preparedness and real time contingent measures to deal with weather aberrations. Also, the alternate crops tolerant to wild animal damage are tested and are being recommended to the farmers of the region.

New challenges are being faced by the farmers of the region because of changing climatic scenario and damage of crops by wild animals. The centre is working for the development of the technologies suitable under aberrant weather conditions. The technologies being generated at this centre are also having relevance in the *Kandi* region of adjoining states like Himachal Pradesh. The rainfed crop varieties developed at the centre are being adopted by the farmers of that region also. Now a close linkage has been developed with research and extension system of these adjoining state agricultural universities so that technologies developed by AICRPDA centre are disseminated to these regions also in the nation's interest. So it will be in the interest of farming community of *Kandi* region if the AICRPDA main centre continues to remain at RRS, Ballowal Saunkhri.

The integrated farming system approach for judicious use of natural resources under rainfed and limited water conditions needs to be tested. As the scarcity of water is increasing even in the irrigated regions, the technologies developed under this project at the centre shall have relevance in those situations also. The farmers' participatory research component needs to be enhanced for developing relevant technologies and to get benefit from the ITK of the farmers.